First results from the aerosol lidar and backscatter sonde intercomparison campaign STRAIT'97 at Table Mountain Facility during February–March 1997

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1 Abstract

First results of an intercomparison measurement campaign between three aerosol lidar instruments and in-situ backscatter sondes performed at Table Mountain Facility (34.4°N, 117.7°E, 2280 m asl) in February–March 1997 are presented. During the campaign a total of 414 hours of lidar data were acquired by the Aerosol-Temperature-Lidar (ATL, Goddard Space Flight Center) the Mobile-aerosol-Raman-Lidar (MARL, Alfred Wegener Institute), and the TMF-Aerosol-Lidar (TAL, Jet Propulsion Laboratory), and four backscatter sondes were launched. From the data set altitude profiles of backscatter ratio and volume depolarization of stratospheric background aerosols at altitudes between 15 and 25 km and optically thin high-altitude cirrus clouds at altitudes below 13 km are derived. On the basis of a sulfuric acid aerosol model color ratio profiles obtained from two wavelength lidar data are compared to the corresponding profiles derived from the sonde observations. We find an excellent agreement between the in-situ and ATL lidar data with respect to backscatter and color ratio. Cirrus clouds were present on 16 of 26 nights during the campaign. Lidar observations with 1–7 minute temporal and 120–300 m spatial resolution indicate high spatial and temporal variability of the cirrus layers. Qualitative agreement is found between concurrent lidar measurements of backscatter ratio and volume depolarization.

2 Introduction

Ground-based lidar observations of the stratosphere are an integral part of the Network for the Detection of Stratospheric Change (NDSC). The high quality level of the NDSC data set is guaranteed by periodic intercomparisons between measuring instruments [e.g., *McDermid et al.*, 1995]. Here we report on results from an intercomparison campaign which has taken place at the NDSC complementary station Table Mountain Facility in southern California (34.4°N, 117.7°E, 2280 m asl) between February 19 and March 18, 1997. Three aerosol lidar instruments participated in the campaign:

- a mobile aerosol Raman lidar (AT-Lidar or ATL) *Gross et al.* [1995] from Goddard Space Flight Center (GSFC), USA,
- a mobile aerosol Raman lidar (MARL) [*Schäfer et al.*, 1995] from Alfred Wegener Institute for Polar and Marine Research (AWI), Germany, and
- an aerosol lidar (TAL) from Table Mountain Facility / Jet Propulsion Laboratory, USA.

Four balloon-borne backscatter sondes (BKS) [*Rosen and Kjome*, 1991] from University of Wyoming were launched to provide independent data on aerosol backscatter coefficient.

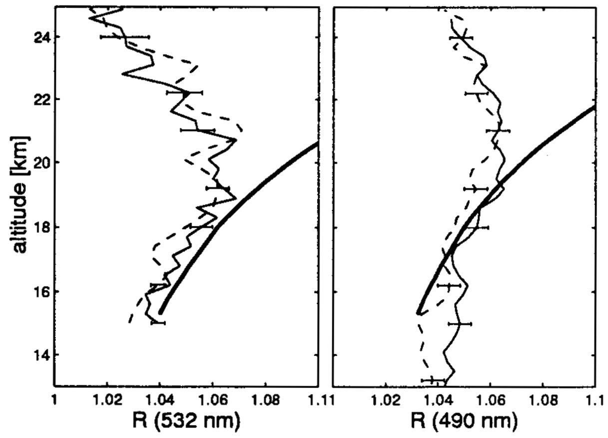

Figure 1: Backscatter ratio at 532 nm (AT-Lidar, left panel) and 490 nm (BKS, right panel) as observed on March 11 (full line) and March 13, 1997 (dashed line). The thick lines give the result obtained by the aerosol model.

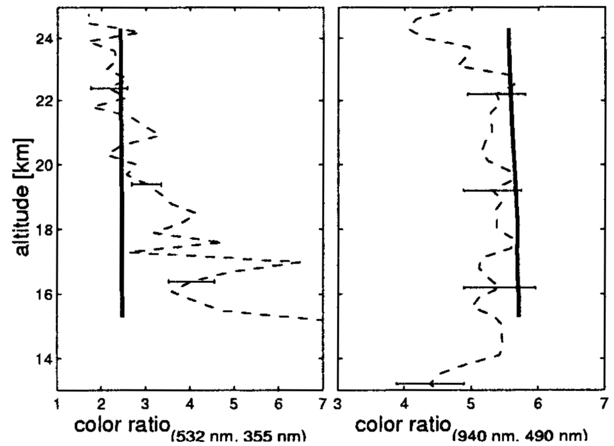

Figure 2: Color ratio at 532 nm, 351 nm (AT-Lidar, left panel) and at 940 nm, 490 nm (BKS, right panel) as observed on March 13, 1997 (dashed line). The thick lines give the result obtained by the aerosol model.

3 Results and discussion

The three aerosol lidar systems were placed in close vicinity. The distance between MARL and TAL was about 30 m, the AT-Lidar was located at a distance of about 500 m. Test measurements showed that all three aerosol lidar could be operated simultaneously with no detectable interference or cross-talk between the instruments. During the campaign a total of 413.6 hours of lidar data were acquired by the three instruments.

3.1 Stratospheric background aerosol

In order to compare the lidar observations of the stratospheric background aerosol (SBA) layer with the in-situ data an aerosol model is used [*Steele and Hamill*, 1981]. The model is based on the assumption that SBA consists of H_2SO_4/H_2O droplets in equilibrium with 5 ppmv ambient water vapor mixing ratio [*Hamill et al.*, 1997]. The size distribution $d\mathcal{N}/dr$ is assumed to follow a log-normal distribution,

$$\frac{d\mathcal{N}}{dr} = \frac{\mathcal{N}_0}{\sqrt{2\pi}\, r \ln \sigma_g} \exp\left(-\frac{\ln^2(r/r_m)}{2 \ln^2 \sigma_g} \right) \qquad (1)$$

where $\mathcal{N}_0$, r_m, and σ_g denote the particle number density, the median radius, and the geometric standard deviation, respectively. *Pinnick et al.* [1976] give the parameterization $\mathcal{N}_0 = 10$ cm^{-3}, $r_m = 0.075$ μm, and $\sigma_g = 1.86$. We assume $\mathcal{N}_0$, r_m, and σ_g to be constant throughout the aerosol layer.

The wavelength dependence of the aerosol backscatter coefficient β^A can be expressed in terms of the color ratio

$$C_{\lambda_1,\lambda_2} = \frac{R(\lambda_1) - 1}{R(\lambda_2) - 1} = \frac{\beta^A(\lambda_1)}{\beta^A(\lambda_2)} \left(\frac{\lambda_2}{\lambda_1} \right)^k . \qquad (2)$$

Here, R is the backscatter ratio at wavelength λ and $k = -4.13$ denotes the wavelength dependence of molecular scattering [*Ciddor*, 1996].

In Figure 1 the enhancement of backscatter ratio due to the presence of the SBA as observed by AT-Lidar and BKS sonde on March 11 and 13, 1997 is shown. The lidar measurement time periods were 6.5 h and 5.5 h, respectively. Both, the lidar and sonde observations are in good agreement with the model results (thick lines) at altitudes between 15 and 19 km.

Figure 2 shows the color ratio calculated from the lidar and in-situ data at 532 nm, 351 nm and 940 nm, 490 nm, respectively. We find a good to excellent agreement between observations and the model calculations (thick lines). As color ratio does not depend on particle number density $\mathcal{N}_0$ (Equation 2) the agreement with respect to C (Figure 2) above 19 km and disagreement with respect to R (Figure 1) suggests that $\mathcal{N}_0 < 10$ cm^{-3} above 19 km.

3.2 High-altitude cirrus

During the campaign cirrus clouds were observed on 16 of 26 nights. Analysis of high temporal resolution data (6.6 and 1 minute for MARL and TAL, respectively) reveals a strong spatial and temporal variability of the observed cirrus clouds.

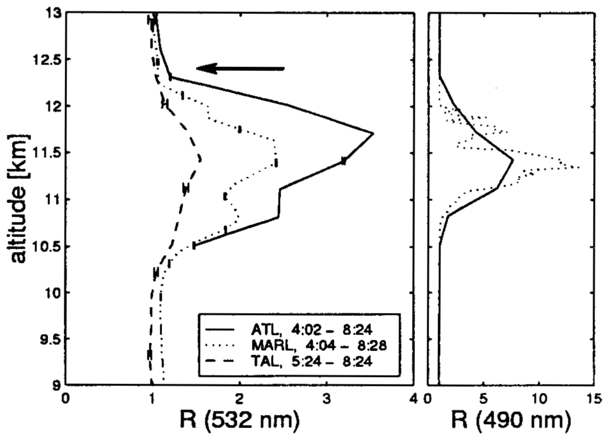

Figure 3: Cirrus cloud observation by lidar (left panel) and in-situ sonde (right panel) on March 11, 1998. All profiles have been converted to a common altitude resolution of 600 m. Lidar integration times vary between 3 and 4.5 h. (The dotted line in the right panel marks the original profile.) Tropopause altitude is marked by an arrow.

In general, the layers extend vertically over 1–2 km; occasionally, clouds appear in several distinct layers separated by 1–2 km. Cirrus clouds are found in close vicinity below and at tropopause altitudes. There is no indication for cirrus occurrence in the lower stratosphere.

Figure 3 shows the cirrus cloud observation of March 13, 1997. The tropopause altitude is derived from the in-situ temperature profile. In order to facilitate the comparison all backscatter ratio profiles are converted to a common altitude resolution of 600 m. We find substantial differences not only between sonde and lidar profiles but also between lidar observations. For example, values of R obtained by ATL and MARL deviate by almost 50% despite an almost identical measurement period and an integration time of several hours.

These deviations are caused by a strong temporal and spatial variability of cirrus clouds as can be seen from Figure 4–7. In Figures 4 and 6 the temporal evolution of backscatter ratio at 532 nm is plotted as a function of altitude and time. The tropopause altitude is derived from the in-situ temperature profile. Taking into account that the temporal and vertical resolutions of the underlying data set are not identical (1 minute/300 m and 6.6 minutes/120 m for TAL and MARL, respectively) a general similarity between Figures 4 and 6 is observed. We note that for the graphical representation the data sets have been interpolated in time using Gaussian weights with a standard deviation of 1.5 minutes.

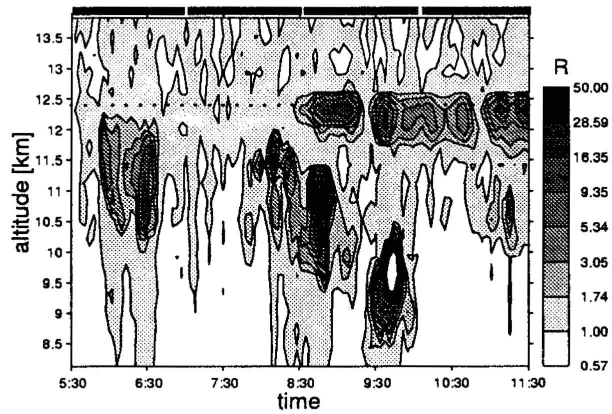

Figure 4: Temporal development of cirrus layers on March 13, 1997 as observed by TAL. Backscatter ratio at 532 nm is shown as a function of altitude and time. The tropopause altitude is marked by a dotted line. Bars above the figure indicate the time of the individual measurements.

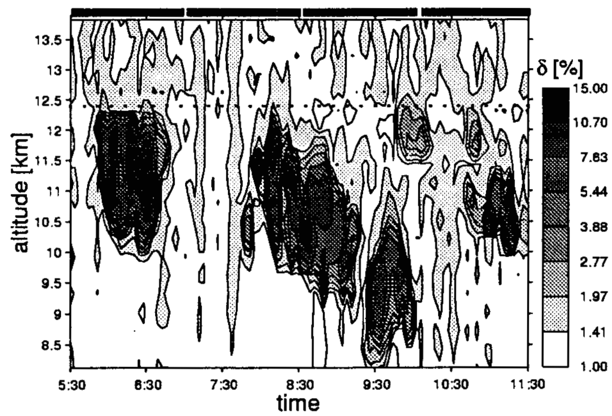

Figure 5: Temporal development of volume depolarization at 532 nm on March 13, 1997 as observed by TAL. The tropopause altitude is marked by a dotted line.

Likewise, the temporal evolution of volume depolarization $\delta = \beta_{\perp}/\beta_{||}$ show qualitative agreement (Figures 5 and 7). ($\beta_{||,\perp}$ denote the backscatter coefficient in the aligned- and cross-polarization detection channel, respectively.)

4 Conclusions

Based on our observations we draw the following conclusions.

- Good or excellent agreement is found between lidar and in-situ measurements of the stratospheric background aerosol.

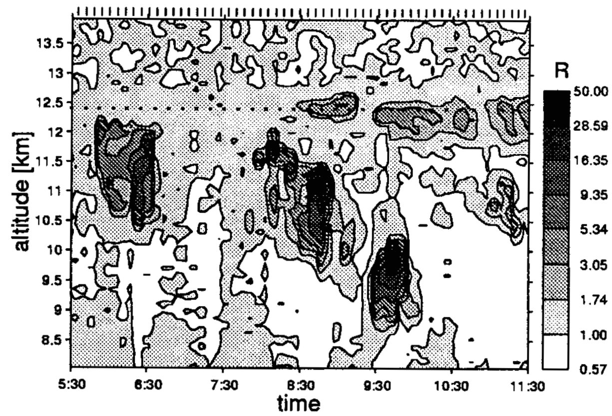

Figure 6: Temporal development of backscatter ratio at 532 nm on March 13, 1997 as observed by MARL. The tropopause altitude is marked by a dotted line.

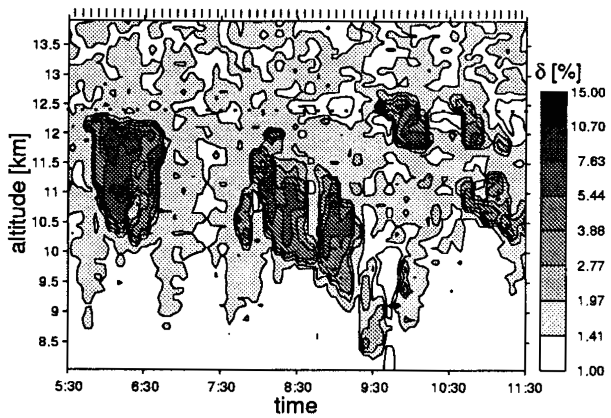

Figure 7: Temporal development of volume depolarization at 532 nm on March 13, 1997 as observed by MARL. The tropopause altitude is marked by a dotted line.

- Frequently cirrus clouds are observed in close vicinity below and at the tropopause. There is no indication that cirrus cloud occur in the lower stratosphere.

- The cirrus layers exhibit a high degree of spatial inhomogeneity.

- In-situ and lidar observations show vertical scales on the order of several tens of meters.

- The vertical and horizontal extend of cirrus clouds can accurately be mapped by the high-resolution lidar data set.

5 Acknowledgments

Financial support by Alfred Wegener Institute, Germany and the National Aeronautics and Space Administration is gratefully acknowledged. The work described in this paper was carried out at the Jet Propulsion Laboratory, California Institute of Technology, through an agreement with the National Aeronautics and Space Administration. GB thanks National Research Council for the award of an associateship.

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